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Climate Change Impacts on Native Plant Communities in Melanesia

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Synopsis

Melanesia is a hotspot of diversity for vascular and non-vascular plant species, with estimated species endemism as high as 80% for New Guinea. The current lack of site-specific climate and species information is a major impediment to the assessment of possible effects of climate change on islands within Melanesia. Plant communities predicted to be impacted most by the effects of climate change are the mangrove and coastal systems, montane systems, and dryland vegetation communities. However, anthropogenic effects, such as land-clearing, logging, and fire, may have greater effects on diversity in the short-term. Research needs for the area include intensive botanical surveys, physiological and phenological assessments of plant species to the effects of climate change, and long-term monitoring to determine baseline and trends in biodiversity and community structure.

This paper summarizes the limited amount of information known about the effects of climate change on native plant communities ranging from subsurface to montane ecoregions in Melanesia, which includes the islands of New Guinea (Papua New Guinea and Papua), the Solomon Islands, Vanuatu, Fiji, and New Caledonia. Agricultural and human modified systems (e.g., forestry plantings) will not be considered within the scope of this paper.

Introduction

Although geological records show climatic changes throughout history (e.g., Bush *et al.* 2004, Hope 2008), the rapidity of the present rate of global warming threatens the survival of entire ecosystems. Climate change is predicted to cause an increase in average air temperature of between 1.4 °C and 5.8 °C, increases in atmospheric CO_2 concentration, and significant changes in rainfall pattern (Houghton *et al.* 2001). Humidity and temperature over the tropical western Pacific have been increasing since the mid-1970s (Still *et al.* 1999), but to date, the average annual temperature has increased by less than 0.5 °C (Watson *et al.* 1997). Numerous bioclimatic models are being developed to estimate the relationship between the current and future distribution of species and climate, but there is often little consensus regarding the performance of these models (Araujo & Rahbek 2006), and they are not useful at the regional scale needed for Melanesia. Intensification of weather extremes due to climate change may accelerate shifts in plant species composition and distribution (see Jentsch *et al*. 2007 for review). Forests themselves have an important role in regulating the local and regional climate. These factors further undermine the modeling and prediction of changes to vegetation distribution, composition, and diversity.

Because such a high proportion of native plant species found in Melanesia are endemic (Table 1), the actual and potential effects of climate change on global biodiversity may be correspondingly large. Large numbers of these endemics have highly restricted distributions, occurring in one or few localities, and often in a very limited number of small, localized populations (e.g., Lowry 1998). Species known from only a single locality or single population are expected to be at most risk of extinction due to the potential effects of climate change.

Table 1. Estimates of current land area occupied by vegetation types, predicted loss of land area by 2100, the percentage endemic species (of total vascular species), number of endemic genera, and the current estimated number of native (endemic and indigenous) species for Melanesian island groups. Numbers in brackets are the number of native species recorded from each particular vegetation or species type.

	% Land area[a]	**% Predicted loss by 2100[c]**	**% Endemic species**	**No. endemic genera**	**No. native vascular species**
Papua			**60-90**		**20,000-25,000**
Lowland rain forest	56.6				
Montane rain forest	13.3				
Inland swamp	12.1				
Coastal vegetation	9.1				
Mangrove [c]	4.3	0-8?			(43?)
Seagrass[f]					(13)
Papua New Guinea			**70-80**	**>86**	**11,000-20,000+**
Lowland rain forest	50.9				
Montane rain forest	14.1				
Inland swamp	14.3				
Lowland monsoon forest	0.7				
Mangrove [c]	0.8-1.2	0-8			(33)
Seagrass[f]					(13)
Hepatics (mosses, liverworts)[e]			38		
Solomon Islands			**0.9**	**4**	**2,780-5,000**
Lowland rain forest	90.1				
Montane rain forest	2.8				
Mangrove [c]	2.2	0			(20)
Seagrass[f]					(7-9?)

Vanuatu			**17**	**1**	**870**
Forest	75				
Mangrove [c]	0.2	0-19.8			(14)
Seagrass[f]					(10)
Fiji			**22-63**[b]	**6**[b]	**1,290-1,769**
Rain forest	33-(65)				
Mangrove [c]	2.2	13.7-57.5			(8)
Seagrass					(4-6)
New Caledonia[d]			**77**	**110**	**3,380**
Evergreen rainforest (lowland & montane)	18-22		87.2	97	(2,009)
Sclerophyllous forest	2.2		58.8	11	(379)
Maquis	30		40	58	(488)
Dune systems			10		(150)
Mangrove [c]	1.1	0-14			(14)
Seagrass[f]					(11)

[a] From Van Royen & Davis (1995), Davis *et al.* (1995)
[b] Heads (2006)
[c] Mangrove data from Gilman *et al.* (2006)
[d] Data for New Caledonia from Lowry (1998)
[e] Piipo (1994)
[f] World Atlas of Seagrasses (http://www.unep-wcmc.org/marine/seagrassatlas/)

The flora within the Melanesian region has been strongly influenced by geological history and historical climatic influences. Vegetation in the area consists of Australasian, Malesian, Pacific, and South American components. For instance, 35% of Fijian flora consists of pantropical genera, 55% old world and Malesian genera, and 10% are endemic genera (Smith 1996). Endemism and biodiversity estimates are constantly changing due to the description of new species, amalgamation of species, range extensions of species previously thought to be endemic to another region, and extinctions.

Responses of native plant communities to projected environmental changes

Climate change is predicted to shift species geographical ranges as a result of modifications to the normal patterns of temperature and humidity that generally delimit species boundaries (Thuiller 2007). Many studies predict that climate change impacts will consist largely of shifts in latitudinal and altitudinal distributions (Thuiller 2007, Williams *et al.* 2003, Watson *et al.* 1997). Most plant community types in Melanesia will probably experience fine-scale shifts in species composition depending on the tolerance ranges for each species to the combination of changing climatic variables. Alterations in population size, species distribution, and the geographical extent of habitats and ecosystems, as well as an increase in the rate of species extinction and loss of biodiversity can be expected. The greatest biodiversity change might be expected near climatically determined boundaries of species distribution, and the ability of species to respond to climate change will largely depend on their ability to colonize new territory or modify their physiology and seasonal behavior. Plants with broad climatic tolerances should be able to remain in equilibrium with change, but for taxa with narrow ranges, the current predicted rate of climate change may move them outside their climatic niche space within only one or two plant generations (Bush *et al.* 2004). Landscape fragmentation, competition from invasive species, lack of available habitat, or absence of a necessary environmental factor, such as a specific soil type, microbial community or water availability, will impede migration.

Because of the high diversity and endemism of plant species within Melanesia, the potential for species loss due to climate change could be large. Many publications predict that overall biodiversity in the equatorial belt is likely to suffer more immediately from deforestation and land degradation than from climate change (e.g., Thuiller 2007, Sala *et al.* 2000). For instance, Brooks *et al.* (2002) estimated that 19% of New Caledonian plant taxa are listed as threatened or extinct, and this increases to 31% with the loss of 1000 km^2 habitat. By contrast, one model used to assess extinction risks for Amazonian plant species predicted the loss of biodiversity due to habitat loss as a result of human-caused land conversion ranged from 4-8%, while extinction due to maximum expected climate change ranged from 36-79% taking into account dispersal, or 87-100% if no dispersal occurred (Thomas *et al.* 2004). Part of the uncertainty in predicting changes to biodiversity is that our knowledge of the Melanesian flora is limited and many more species may already be threatened than are currently recorded on the IUCN Red List. Currently, less than 1% of the flora is listed as vulnerable or above for New Guinea, Vanuatu, and the Solomon Islands. By contrast, for the well documented floras of Fiji and New Caledonia, 6% of native species are listed as threatened.

Montane ecosystems

The general understanding is that with an increase in air temperature as a result of climate change, the coldest climatic zones will disappear. Habitat for species unable to survive and reproduce in warmer climates will shift upslope and shrink in area. Higher mountains and isolated mountain ranges can support very high levels of local endemism and may be the first ecosystems in which species become extinct. For instance, endemism in New Guinea is highest in the montane zone as a result of environmental change induced by rapid rates of geological uplift and the increasing richness of epiphytes, hepatics, and shrubs (Davis *et al.* 1995, Piipo 1994, Takeuchi 2007). Glaciers in New Guinea have been observed and documented as having decreased substantially in size indicating that freezing heights may have already shifted upslope along with declines in precipitation (Hope 2008).

All of the high peaks on Melanesian islands are regularly enveloped by tradewind-derived orographic clouds, resulting in the presence of unique and diverse floral assemblages of variable and patchy structure. These cloud forests are adapted to high precipitation due to the deposition of cloud droplets and convective rainfall, low radiation, cooler temperatures, and often high winds (Mueller-Dombois & Fosberg 1998). The lower limits of cloud forests are determined by moisture availability, with clouds contributing 37% of moisture budgets for these habitats (Bush *et al.* 2004). Simulations of climate change suggest an upslope shift of the cloud layer, which may exacerbate the effects of longer and more variable dry seasons in these areas as predicted by global climate change models (Pounds *et al.* 1999, Still *et al.* 1999, Williams *et al.* 2003). An increase in air temperature associated with climate change implies increased evapotranspiration by vegetation which, in combination with reduced cloud contact, could have serious implications for biodiversity (Still *et al.* 1999).

Mangroves and coastal strand

Mangroves are a taxonomically diverse group of salt-tolerant flowering plants that grow primarily in tropical and subtropical regions in the intertidal zones of marine coastal environments or estuarine margins. Mangrove communities are documented for all island groups in Melanesia, with diversity declining from New Guinea, south to New Caledonia and Fiji (Table 1, Davis *et al.* 1995, Gilman *et al.* 2006, Mueller-Dombois & Fosberg 1998), and are biologically rich. For example, New Guinea has a high diversity of mangrove species (Table 1), and the genetic diversity in Fiji declines with altitude from sea level, with 80 plant species being associated with the eight mangrove species (Heads 2006). Climatic factors, such as temperature and moisture, affect the distribution of mangroves (McLeod & Salm 2006). While mangroves are not expected to be adversely affected by projected increases in sea temperature, increases in air temperature have been shown to impact development, with temperatures above 35 °C leading to thermal stress which affect root structure and the establishment of seedlings. Decreased precipitation, resulting in increased salinity, reduces the growth and survival of mangroves, and may change the species composition and diversity.

Projected increases in the frequency and level of extreme high water events with climate change could affect the position and health of coastal ecosystems. Mangroves and coastal vegetation provide protection from coastal erosion and damage by tidal surges, currents, rising sea levels, storm energy in the form of waves, and cyclones (Gilman *et al.* 2006). Roots bind and stabilize the substrate and form habitat for other biota, such as providing fish and crustacean nurseries. The projected losses for Melanesian archipelagos are highly variable due to the uncertainty in predicting sea level rise (Table 1, Gilman *et al.* 2006). Mangroves migrate landward as a natural response to rising sea level. Where this is not possible as a result of natural or artificial barriers to migration, mangrove area may be reduced over time. Slow rates of mangrove sedimentation and the possibility of subsurface sediment subsidence due to organic matter breakdown, sediment compaction, and changes in water fluxes may result in inundation, reducing the survival of mangroves. Mangroves with low sediment supply may not be able to keep up with future rates of sea-level rise. By contrast, in some protected coastal settings, inundation of low-lying coastal land may actually promote progressive expansion of mangrove forest with rising sea level. Global warming may facilitate mangrove expansion into saltmarsh communities, in turn reducing their diversity. Ultimately, the survival, composition, and diversity of mangrove communities will depend on regional factors, such as groundwater availability, salinity, substrate type, sediment input, rather than overall global changes (Gilman *et al.* 2006, McLeod & Salm 2006).

Coastal erosion, partly the result of anthropogenic factors such as sand mining, is already a problem on many islands and may be exacerbated by sea-level rise (Mimura and Nunn 1998). Carbonate beaches are maintained by sand produced from productive reefs whose degradation may result in accelerated beach erosion. The impact of climate change on beach development, and the habitat of coastal strand, could be severely impacted by climate change (Coles 2008).

Seagrass communities & aquatic communities

Seagrasses serve as feeding grounds and nursery habitat for many commercially and recreationally important fish and marine species, and the roots and rhizomes bind and stabilize sediments, improving near-shore water quality. Increases in global temperature and CO_2 have been shown to alter growth rates and other physiological functions of seagrasses under controlled conditions (Short & Neckles 1999). However, because taxa show different responses, species distribution will most likely shift as a result of increased temperature stress and changes in the patterns of sexual reproduction. Eutrophication and changes in frequency and intensity of extreme weather events will also alter species distributions. Sea level rise will result in an increase in water column depth, and potential changes in tidal variation and altered water movement may affect salinity, turbidity and light availability, resulting in a redistribution of existing habitats. Changes in the deposition of sandy substrate will also shift community structure.

For other freshwater aquatic species and communities, there is little literature regarding the effects of climate change. A decline in river flow rates due to reduced precipitation, changes in precipitation patterns, flood duration, or increased withdrawal for agriculture and other human uses, could have implications for the diversity of aquatic, swamp, and wetland species. For freshwater ecosystems, biotic exchange may be much more important than the effects of climate change (Sala *et al.* 2000). Higher concentrations of dissolved CO_2 typically result in increased photosynthetic activity, but this is not necessarily reflected in the increased growth of aquatic species. However, an increase in the ratio of carbon to nitrogen provides poorer quality forage for vertebrates. Changes in salinity due to inundation will affect aquatic species distributions.

Elevated CO_2 concentrations

Plants differ in their direct physiological response to elevated CO_2, as well as in the less obvious responses such as changes in tissue composition, stress resistance, or rhizosphere interactions (Korner 1998). While rising CO_2 concentrations are projected to increase productivity of some communities and alter competition among others by eliminating species and introducing new species to take their place (McCarthy *et al.* 2001), the realized effects of increased concentrations of CO_2 are unclear. For example, studies that doubled the concentration of CO_2 over temperate short-grass steppe had little impact on plant species diversity, but resulted in increased biomass of woody shrub species (Morgan *et al.* 2007).

Precipitation changes

All of the Melanesian island groups have distinct windward and leeward vegetation types due to orographic differences in rainfall (Davis *et al.* 1995, Mueller-Dombois & Fosberg 1998). Long term trends for rainfall in the face of global climate change are difficult to ascertain, and are neither spatially nor temporally uniform (Sala *et al.* 2000, Walther *et al.* 2002, Watson *et al.* 1997). Reduced precipitation due to climate change, particularly in leeward habitats, may result in greater susceptibility of the vegetation to fires, and the replacement of forests with shrublands, grasslands, or savanna ecosystems (Gullison *et al.*, 2007). Even in non-ENSO (El Nino Southern Oscillation Event) years, global warming may be placing tropical forest regions at risk of more frequent and severe droughts. The most consistent pattern for species distribution in tropical forests worldwide is the regional and continental distribution of rainfall and soil water availability. Seasonality and physiognomy (leaf flush and flower production) of tropical forests are mainly determined by the amount of annual rainfall and its seasonal distribution (Borchert 1998). For instance, the sensitivity of tropical seedling and tree species in Panama has been found to shape plant distributions at both the regional and local scale (Engelbrecht *et al.* 2007). Changes in soil moisture availability caused by global climatic change and forest fragmentation are likely to alter tropical species distributions, community composition, and diversity. Conversely, predicted climate change may be unlikely to affect the physiognomy of rainforests with high annual rainfall and low seasonality, such as those of New Guinea. As the limits of drought tolerance of Melanesian rainforest species are not known, the rate and extent of future changes cannot be predicted at this time.

Catastrophic disturbances

The forests of Melanesia are subjected to frequent damage and disturbance by cyclones, landslides, earthquakes, and changing river courses (Davis *et al.* 1999, Whitmore 1969). However, forests have co-evolved with these natural disturbance factors over long periods of time, and they are part of the overall dynamic of forest ecosystem and give rise to diversity. Cyclones are catastrophic windstorms (high winds and heavy rain) that cause high rates of defoliation, uprooting, and snapping of stems and branches of trees in the storm’s path. Recovery typically takes place through resprouting, regeneration from seed, or understory seedlings and saplings. The study of the recruitment and survival of tree species in Solomon Islands over a 30 year period after the impact of four cyclones in a 9-year period showed no evidence of spatial variation in tree species composition (Burslem *et al.* 2000), indicating the potential resilience of these systems to such disturbances.

Drought and associated fires resulting from the periodic ENSO climatic cycles are a significant ecosystem disturbance in Melanesia. For example, maquis vegetation on ultrabasic soil types and the sclerophyllous forest vegetation of New Caledonia is substantially more vulnerable to fires which are especially widespread during the dry season and in areas with lower levels of precipitation (Lowry 1998, Mueller-Dombois & Fosberg 1998). Such dryland vegetation has a high level of endemism (Table 1), but fire reduces the vegetation from forest-type to shrub-type communities, with frequent fires reducing the flora to fern or grasslands. Vegetation diversity of ultrabasics in the Solomon Islands have also been dramatically altered or reduced by fire (Whitmore1969).

Genetic implications

The natural capacity of Melanesian species to adapt to changing climate is unclear. Genetic diversity plays a critical role in the survival of populations in rapidly changing environments. Tropical forest plants may respond to climate change through phenotypic plasticity, adaptive evolution, migration to a suitable site, or localized or outright extinction (Bawa & Dayanandan 1998). Whitmore (1969) noted that many tree species in the Solomon Islands have wide ecological ranges, but little research has been undertaken within Melanesia. Along with changes in phenology, reduced genetic diversity due to forest fragmentation and deforestation as a result of human activity or climate change, may reduce genetic variation by causing extinction of genetically unique populations, promoting inbreeding, and disrupting gene flow. The response of forest trees to climate change will also depend upon the responses of, and interactions with, a wide variety of other organisms. Changes in climate during critical phases of the life cycle such as flowering, seed development, and seedling establishment, may have much greater effects than the direct effects of climate change. The rate at which species can respond or genetically adapt to climate change will be dictated by their life span and generation cycle. Even more critical for spatially and environmentally variable Melanesian systems is that different plant species and even genetically distinct populations of the same species may have unique ecological niches and may respond differently to change in climate.

Consequences of climate change for ecosystem services to humans & natural resource management

A significant proportion of native peoples within Melanesia depend directly on forests and the plants they contain for subsistence and well-being (e.g. Davis *et al.* 1995, McClatchey *et al.* 2005, Whitmore 1969). A significant number of species are used as a food source, including fruit, nuts, forages, vegetables, spices, and condiments. Plants are used as a source of fiber and rattan, for the production of exudates, poisons, dyes, and tannin; and other items such as weapons, clothing, and containers. Wood is used as a fuel source, and forests provide the raw materials for building houses and shelters. Many native plant species are used as traditional medicinal plants. For example, in Papua New Guinea, 25 species are used in treating fevers, including malaria; 40 species for treatment of cough, cold and sore throats, and a further 25 species are associated with control of fertility and childbirth (Van Royen & Davis 1995). Many native plants have spiritual and cultural uses in ceremonies, rituals, and magic. Native plant communities provide habitat for many endemic insect, bird and animal species, not to mention the many micro-organisms (fungi, bacteria) that rely on vegetation for survival and are an essential component in the conservation of biodiversity and wildlife habitat. Eco-tourism can provide significant benefits to the local and national economy and generate income for protected areas, but relies on unspoiled natural environment. As such, the number of visitors to particularly sensitive areas should be regulated in order to prevent irreparable damage to certain vegetation types (e.g., montane communities) that are particularly vulnerable to both human impacts and climate change.

Most development and infrastructure on Pacific Islands is restricted to coastal areas. Losses to coastal vegetation communities because of sea level rise or changes in hydrology as a result of climate change may exacerbate coastal hazards, increasing threats to human safety and shoreline development. Functional links between coastal ecosystems, including mangroves, seagrass beds, and coral reefs, and the biological diversity contained within them, mean that impacts to one component will adversely affect other habitats. Mangroves are estimated to provide products and services, ranging from coastal protection to habitat for fish nurseries, to the estimated value of $200,000–900,000 per hectare (Gilman *et al.* 2006).

Forests are an integral part of the hydrological cycle, and as such the question of how climate change will affect precipitation, forest transpiration, and runoff is a critical question. Native vegetation cover is important for preventing and reducing soil erosion. Changes in river runoff will affect the yields of rivers and reservoirs the recharging of groundwater supplies. Deforestation and other forms of disturbance have a significant feedback effect on hydrology both regionally and globally, impacting other freshwater and marine ecosystems. For example, Bradshaw *et al.* (2007) demonstrate that deforestation results in an increase in flood frequency and total flood duration, with serious economic and societal implications.

Rainforest in Fiji, the Solomon Islands, and New Guinea is being lost at a rapid rate due to logging, and this loss of forest may have greater effects on biodiversity loss than climate change. Harvestable products mostly consist of lowland forest species, with native species supplying 13% of New Caledonia’s timber needs (Van Royen & Davis 1995). The export of forest products from Melanesia significantly contributes to the economy of the area, and the potential loss of habitat for native forest and economically valuable species with climate change could have significant consequences. Repeated burning throughout the region, both present day and historically (Hope 2008), has reduced forested areas and changed the structure and composition of the forest assemblage. Disturbances such as repeated fires or logging on an area may make native plant communities vulnerable to invasive species, further threatening intact native vegetation.

Research Needs

Much of the documentation of climate variability has come from the Northern Hemisphere, and there is very limited long-term ecological analysis for vegetation from Melanesia. The tropical forests of Melanesia are large stores of biological diversity that require study in the face of climate change, but such research will require collaboration between scientists with a broad range of backgrounds, including taxonomists, biologists, climate modelers, atmospheric scientists, economists, and sociologists. In particular, climate modeling or long-term monitoring is critical to the understanding of local and regional climate change. While models have been developed for certain continents or across global ecoregions (e.g. Gonzalez *et al.* 2005), little work has been done to downscale to a regional level. The following research areas require concerted effort in order to understand the impacts of climate change in Melanesia.

Intensive botanical survey and assessment of collections

It is evident from Table 1 that there are large gaps in knowledge of the floral diversity within Melanesia at both the taxonomic and community levels. Without a thorough understanding of the components of ecosystems, conservation cannot proceed and the effects of climate change can not be fully comprehended. Little is known about the current rates of extinction, particularly within New Guinea, and basic baseline data is lacking (e.g. see Campbell & Hammond 1989, Mueller-Dombois & Fosberg 1998). There is no comprehensive description for the vegetation of Vanuatu as a whole (Mueller-Dombois & Fosberg 1998), or for the Solomon Islands (McClatchey *et al.* 2005). The true size of the botanical inventory for New Guinea is unknown and open to considerable speculation (e.g. Table 1, Davis *et al.* 1995, Takeuchi 2003, Damas 1998). Conversely, if the flora is relatively well known, such as Fiji, the current taxonomic status of species remains in flux, and there are often less known or less accessible localities that remain poorly collected. Many areas within Melanesia have a very low collection density (number of specimens per unit area). Molecular systematics and population genetics studies for Melanesia are limited. The georeferencing and mapping of existing collections is a first important step to understanding the distributions of species and community assemblages and would provide a greater idea of biodiversity hotspots in which data need to be obtained. From this, vegetation communities of particular type that do not have a large range, and rare taxa with restricted distributions or niches can be used as a focus to assess the effects of climate change.

Physiological limitation of species and communities

There are few publications of the physiology of Melanesian plant species in relation to predicted climatic changes. Often plant responses to climactic variables are considered only singly as assessments of physiological response, and it is difficult to scale results of experiments up to the landscape and regional levels and generalize across ecosystem types and processes. Species used in such studies also tend to have a short life history, which will not necessarily be the case for tropical species in Melanesia. Choosing target species for which climate change will have the greatest impact should be the first focus for physiological studies. Broennimann *et al.* (2006) have modeled the vulnerability of species and life forms to climate change based on geographical distribution, niche breadth, and migration barriers for South African endemic species and used this data to predict future distribution. There is, therefore, great potential for predicting future Melanesian plant species and community distributions with climate change with the collection of baseline data and further research.

Long-term monitoring and experimental studies

Long-term observations and surveys have been recorded largely for temperate areas in the Northern Hemisphere (e.g. Thuiller 2007, Parmesan 2006, Root *et al.* 2003), but baseline data for future climate change assessments have only recently become established through the PABITRA (Pacific-Asia Biodiversity Transect) network (e.g. Solomon Islands: McClatchey *et al.* 2005, Papua New Guinea: Takeuchi 2003, Fiji: Tuiwawa 2005, Keppel 2005, Keppel *et al.* 2005, Mueller-Dombois & Daehler 2005). Mountains lend themselves to being natural laboratories as research over the steep gradients can be used to determine the influence of local adaptations and differential response of species to different environmental gradients. Because cloud forests have been reported to be particularly sensitive to climate change, and have a high inherent endemism, it would be logical to establish monitoring protocols in fragmented or disjunct montane areas. Coastal areas, while not biologically diverse, have the greatest economic implications if lost through climate change effects, and should also be actively monitored for changes to plant community composition and distribution.

Phenology and functional ecology

Phenological events, such as flowering and fruiting, are often highly tuned to climatic conditions (Bazzaz 1998). Because there are often strong co-evolutionary interactions between plants and their pollinators and seed dispersers, small changes in climate may decouple these highly specialized associations that may lead to failure of reproduction and reduction of biological diversity. However, little is known about the phenology and ecology of Melanesian plant species. While the composition of plant communities may change, species with the same functional role may take the place of those that become extinct. An understanding of forest regeneration and forest succession will be critical to our understanding of the ability of plant species to migrate or disperse under the expected conditions of climate change. It will also be important for the understanding of the impacts of invasive species on the many plant communities. Invasive species do not constitute a major threat to intact or slightly disturbed vegetation, but can rapidly invade secondary vegetation or severely disturbed vegetation and impede the regeneration of native vegetation. Climate change may also influence plant disease by altering the biological processes of the pathogen, host, or disease-spreading organisms (see Harvell *et al.* 2002). Unfortunately, a combination of climate change, species invasions, and reduced areas of natural habitat is likely to promote biotic homogenization in biodiversity hotspots, and foster unpredictable interactions between plants, animals and micro-organisms.

In conclusion, the current lack of site-specific climate and species information is a major impediment to the assessment of possible effects of climate change on islands within Melanesia. However, there are exciting prospects for future research opportunities in Melanesia that would substantially increase our understanding of these unique vegetation communities and hot-spots of biodiversity.

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